

LA-UR-22-24583

Approved for public release; distribution is unlimited.

Title: Cost-Efficient Construction at Los Alamos National Laboratory

Author(s): Caddick, Jordan Simon

Intended for: Academic Report

Issued: 2022-05-16



Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract 89233218CNA000001. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

COST-EFFICIENT CONSTRUCTION AT LOS ALAMOS NATIONAL
LABORATORY

by

JORDAN SIMON CADDICK

Submitted to the Capstone Project Committee

in partial fulfillment of the requirements for the degree of

Master of Engineering Technical Management

Texas A&M University

Professor,
Project Sponsor,

Dr. Chahriar Assad
Associate Laboratory Director, Capital Projects

Copyright 2022 Jordan Simon Caddick

DEDICATION

This project is dedicated to my wife and daughter, in the hopes that the pursuit of knowledge and consideration of contrasting opinions will be as important to our daughter as it is to her parents, and that she will strive to challenge herself in the perilous and vast ocean of information the world will offer her though she may frequently find herself in calm waters.

TABLE OF CONTENTS

	Page
DEDICATION.....	II
TABLE OF CONTENTS	III
LIST OF FIGURES	V
I. EXECUTIVE SUMMARY	1
II. PROPOSAL.....	3
A. Objective.....	3
B. Problem Background	3
C. Capstone Project Schedule	4
D. Magnitude of the Problem	4
E. Measuring Current and Future Impacts of the Solution	5
F. Qualitative/Quantitative (Mixed) Research Methodologies.....	5
G. Proposed Outcome and Impact.....	6
H. Scope	6
III. BACKGROUND/INTRODUCTION.....	7
A. Home Improvement Gone Awry	7
B. The Cost of Construction.....	7
IV. LITERATURE REVIEW	10
A. Risk-Based Approach to Predict the Cost Performance of Modularization in Construction Projects	10
B. A Critical Analysis of Benefits and Challenges of Implementing Modular Integrated Construction	11
C. The Importance and Necessity of Cost Management of Construction Projects...	12
D. Assessment of Methods for Adjusting Construction Cost Estimates by Geographical Location	13
E. Reducing Construction Costs: European Best Practice Supply Chain Implications	14
F. Self-Perform Versus Subcontract Decision in Construction Contracts.....	15
G. Successful Verification of Subcontracted Work in the Construction Industry	16
H. The Importance of Collaboration in Construction Industry from Contractors' Perspectives	17

I.	An Investigation of the Impact of Cross-Cultural Communication on the Management of Construction Projects in Samoa	18
J.	Cost-saving Environmental Activities on Construction Site – Cost Efficiency of Waste Management- Case Study	19
K.	Early Impacts of the COVID-19 Pandemic on the United States Construction Industry.....	20
V.	METHODOLOGY	22
A.	Research Design	22
B.	Participants	23
C.	Instruments	25
D.	Procedure	27
E.	Data Analysis Plan	28
1)	Quantitative	28
2)	Qualitative	28
F.	Risk Management Process.....	28
VI.	ANALYSIS	30
A.	Is LANL That Expensive?.....	30
B.	SWOT Analysis.....	31
C.	PESTLE Analysis.....	33
D.	Pareto Chart / Root Cause Analysis (RCA)	37
E.	CPI / SPI Analysis	39
VII.	RETURN ON INVESTMENT.....	42
VIII.	RECOMMENDATIONS AND CONCLUSION	43
A.	Recommendation 1: Reduce LANL Overhead.....	43
B.	Recommendation 2: Streamline Construction Codes / Standards.....	44
C.	Recommendation 3: Explore New Construction Techniques	44
D.	Conclusion.....	45
IX.	REFERENCES	46
	APPENDIX A LIST OF ACRONYMS	50

LIST OF FIGURES

	Page
Figure III-I Projects Completed by Year and On Time.....	8
Figure V-I Reasons for Construction Cost Inefficiency	23
Figure V-II Survey Participants Years of Service	25
Figure V-III Survey Audience.....	25
Figure V-IV EVMS Principles [18]	26
Figure V-V Baseline Costs: Maroon Line [18]	27
Figure V-VI Risk Register.....	29
Figure VI-I Cost of Construction	31
Figure VI-II SWOT Analysis	33
Figure VI-III Modular vs. Traditional Construction at LANL.....	36
Figure VI-IV PESTLE Analysis.....	37
Figure VI-V High Construction Costs – Pareto Analysis	38
Figure VI-VI Dataset for Pareto Analysis	39
Figure VI-VII CPI/SPI Project Dataset, Jan 2022.....	40
Figure VI-VIII Cumulative CPI/SPI, Jan 2022	41
Figure VII-I ROI.....	42

I. EXECUTIVE SUMMARY

The construction industry can be fraught with cost, schedule, and scope overruns. Los Alamos National Laboratory (LANL), a Department of Energy (DOE) / National Nuclear Security Administration (NNSA) facility located in Northern New Mexico, seems to be particularly vulnerable to cost and schedule overruns. Since Triad National Security, LLC acquired the management and operating (M&O) contract for LANL in 2018, the group has been striving to reduce the cost of construction across the forty square-mile campus.

By 2026, LANL's goal is to develop thirty plutonium pits per year [1]. In order to support this mission, significant investment in infrastructure and facilities will take place. Therefore, LANL must understand how to build cost-efficiently to achieve a production rate of thirty pits per year. A literature review in section four of this paper explores many theories for the high cost of construction. For example, unrealistic baseline data, improper application of change management, supply chain issues due to LANL's remote location, lack of labor, subcontracting vs. self-performing portions or all of a project, and contracting methods could contribute to a higher construction cost. To understand LANL's unique situation, the author utilized a survey administered to a broad demographic of LANL personnel to understand and postulate solutions to combat high construction costs at LANL.

This research paper suggests that reducing overhead, streamlining construction codes and standards, and exploring novel construction techniques for the LANL campus can all

contribute to decreasing cost and schedule overruns and increasing cost-efficient construction. The findings suggest that LANL can achieve a minimum return on investment (ROI) of 11% by reducing the cost of LANL overhead alone, excluding the cost-efficiencies associated with streamlining and exploring novel construction techniques. The research confirms what most individuals suspect to cause higher construction costs. A remote location, lack of labor, lack of subcontractors, excessive LANL overhead, excessive application of building codes and standards, and adherence to traditional models of construction execution methods are contributing factors to construction cost inefficiencies. The challenge lies ahead for LANL to implement the solutions suggested in this research paper across all groups to attain a cost-efficient construction program.

II. PROPOSAL

A. Objective

Construction at LANL can be unreasonably costly. This project aims to posit the cause of the high construction cost at LANL and advise three strategies resulting in cost-efficient construction at LANL if implemented.

B. Problem Background

Why it costs so much to build at LANL is an oft-asked question. Scientists, associate laboratory directors, and program managers would concur that the cost of building at LANL is too high. Ask the craft or maintenance staff, and they will likely mirror these thoughts. Therefore, the high cost of construction affects everyone at LANL for so many individuals to be cognizant of the issue. The additional burden or multiplier for any type of construction project varies between two to four times the cost of building a commercial structure in the state of New Mexico. This high-cost multiplier is not sustainable and could eventually cause the DOE to cease or divert funding to LANL infrastructure projects or use other entities than Triad to meet mission needs.

Theories abound as it relates to the high cost of construction at LANL. The title of this paper uses the word “efficient” as opposed to “effective” because it is surmised that one of the primary issues driving the cost of construction higher is that LANL fails to be efficient in managing construction projects. Some informal theories assert that human performance issues, stringent security requirements, remote locations, difficulty finding

labor in New Mexico (the state population is roughly two million), subcontractor difficulties understanding the business practices of a large federal entity, and unfamiliarity with nuclear standards and building requirements contribute to cost. These theories are in conjugation with the conjecture that improper application of nuclear building codes and standards contribute to cost. Some would say that burdensome codes and standards need to be applied using a graded approach based on the building type (office, science space, manufacturing facility). Lack of laydown yards and material storage space additionally increase construction costs.

C. Capstone Project Schedule

The project took place over nine months, completed in May 2022. During fall 2021, inputs were identified, key players were contacted for support and input, and the research strategy was fully defined. In the winter of 2021, the survey was developed and implemented and historical data was collected. In spring 2022, all data inputs were processed into information, and recommendations were proposed.

D. Magnitude of the Problem

The magnitude of this problem is significant. Part of LANLs major strategic initiatives within the next five years is to increase plutonium pit production to thirty pits per year. To accomplish this goal, infrastructure, support facilities, and office space must be built to support this initiative. New office spaces must be built to accommodate the influx of personnel. Aging facilities and infrastructure must be revitalized to support

existing operations. If LANL cannot overcome the challenge of building cost-efficiently, it cannot meet the commitment made to the DOE to produce thirty pits per year.

E. Measuring Current and Future Impacts of the Solution

The current impact of the problem is measured by comparing current LANL estimates and recently executed historical cost and schedule data. The potential impact of the solution will be measured by applying cost-saving strategies to projects with a fully executed estimate package expected to begin construction activities within twenty-four months. The ROI will be provided in anticipated savings in thousands of dollars, applied to respective phases and activities of the project.

F. Qualitative/Quantitative (Mixed) Research Methodologies

Mixed (qualitative and quantitative) research methods are used. Quantitative research includes measuring historical cost and schedule actuals versus estimates and comparing construction costs at LANL. A survey is proposed to selected individuals at LANL. This survey is intended to assess opinions related to the cause of the high cost of construction and what can be done to remedy this situation. The survey's respondents include engineering services, project engineering, project management, field engineering, subcontractor technical representatives, project controls engineering, and acquisition services.

G. Proposed Outcome and Impact

The proposed outcome of this project is to provide solutions to lower the cost of construction at LANL. If these solutions are implemented, the total project cost (TPC) could be significantly reduced.

H. Scope

The scope includes unclassified construction projects within the associate laboratory directorate capital projects group (ALDCP) funded by the Weapons Infrastructure Program Office (WIPO). These projects are less than \$20M in TPC. These projects are of varying and mixed occupancy types. Occupancy types relate to the type of facilities, such as research laboratories, general office spaces, and manufacturing facilities.

III. BACKGROUND/INTRODUCTION

A. Home Improvement Gone Awry

A story many individuals will find relatable focuses on the desire for a newly renovated kitchen. The plot is as follows: a homeowner wants to remodel their kitchen. The homeowner shops around for subcontractors and finds a suitable builder that appears to understand the scope of work. Price negotiations ensue and work on the kitchen begins shortly thereafter. Both parties agree the work should take no longer than one month. Six months later and thousands of dollars over budget, the work is three-quarters complete, and both parties have reached an impasse regarding a suitable path forward.

B. The Cost of Construction

Many readers will find this narrative familiar. LANL, too, can relate to this story. One of seventeen National Laboratories under the United States DOE, LANL is under the NNSA's umbrella along with two other National Laboratories: Sandia in Albuquerque, New Mexico, and Lawrence Livermore outside of San Francisco, California. LANL's mission is to solve national security challenges through scientific excellence. LANL's mission manifests itself in nuclear deterrence and stockpile stewardship, protecting the nation against nuclear threats, countering emerging nuclear threats, and enhancing national energy security [2]. Since its establishment in 1943 as a secret facility supporting the Manhattan Project [3], LANL's infrastructure has grown immensely to

support the laboratory's mission. Triad National Security, LLC was awarded the maintenance and operational contract for LANL on 1 November 2018 [4]. Between October 2019 and October 2021, 12% of projects greater than \$1M and less than \$20M in total value have finished on time, as shown in Figure III.I. Projects that exceed their baseline schedule also exceed their budget.

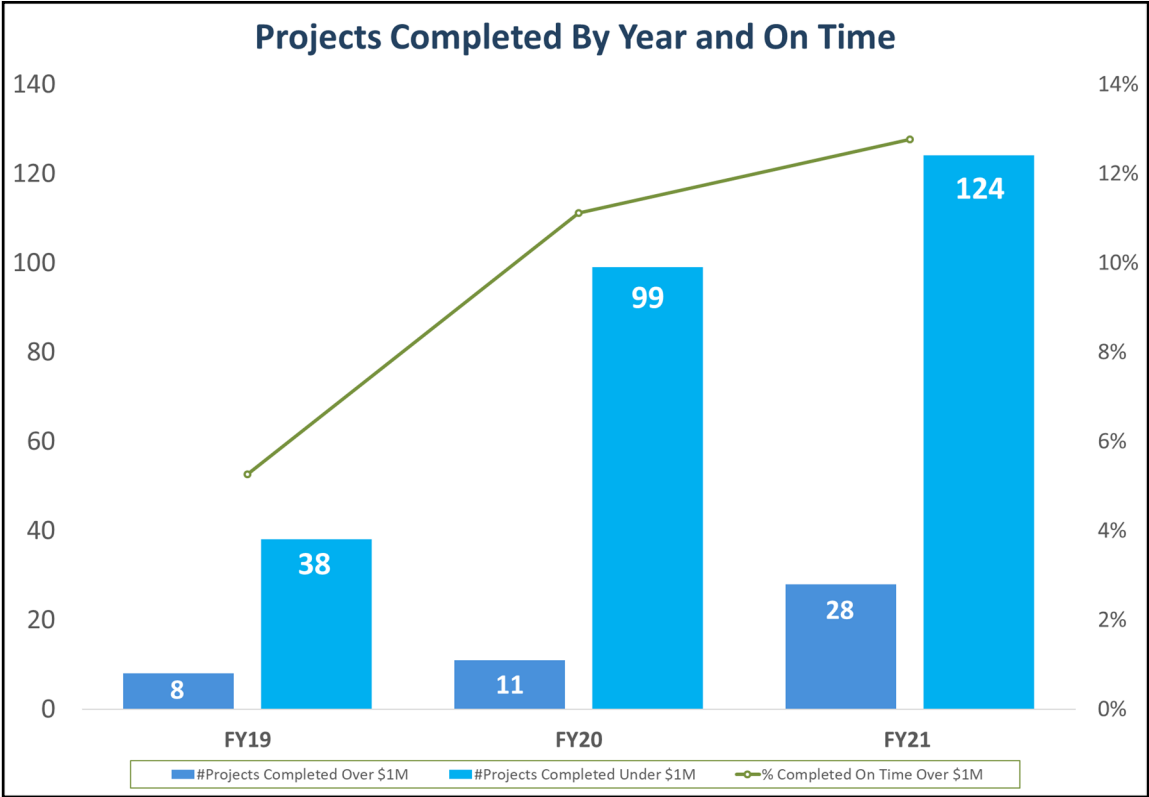


FIGURE III-I PROJECTS COMPLETED BY YEAR AND ON TIME

Why should the average reader at LANL care about this statistic? After all, the subset of projects indicated in Figure III-I represents a small fraction of all construction projects at LANL. Perhaps the reader is employed with one of the other seventeen National

Laboratories across the United States and finds no similarities between their Laboratory and LANL. The essential findings and suggestions in this paper, namely concerning the high cost of construction at LANL, apply to all DOE National Laboratory facilities. As it relates to construction costs, all facilities must comply with the same DOE codes and standards. This means following DOE Order 413.3B, which provides program and project management direction related to delivering projects within the original performance baseline, cost and schedule, and fully capable of meeting mission performance, safeguards and security, and environmental, safety, and health requirements. [5] Finding construction efficiencies at one National Laboratory could translate to millions of dollars of savings across the entire National Laboratory system. By understanding why construction projects exceed their projected budget and schedule, we can determine ways to avoid cost and schedule overruns in the future. This paper argues that by empowering, incentivizing, and equipping the executing organization with clear guidelines and goals, the cost of construction can be reduced at LANL. Most staff at LANL know that the cost of construction is higher than it should be. In this paper, the author will attempt to identify why it is costly to build at LANL. By identifying contributing factors to the high cost of construction, actionable items will be recognized that can reduce the cost of construction.

IV. LITERATURE REVIEW

A. Risk-Based Approach to Predict the Cost Performance of Modularization in Construction Projects

This journal article written by Nabi and El-adaway illuminates an essential solution for cost-efficient construction: modularization. Bayraktar defines modularization as the “fabrication, integration, and assembly of components of a constructed structure or facility at manufacturing plants that then are transported to the construction site” [6]. The primary focus is to present the reader with a risk-based tool to analyze and quantify how the modular approach to construction can impact cost performance.

The dichotomy of modular versus traditional construction, particularly how to quantify and manage the risks unique to each method, is a subject of debate within the industry and especially at LANL. Since Triad National Security was awarded the maintenance and operations contract in November 2018, several projects have been built using a modular construction approach at the LANL campus. However, it is yet to be determined whether this approach is genuinely cost-effective from a short and long-term perspective for LANL because of the lack of reliable cost and schedule data compared to a reliable baseline. In light of a dearth of information unique to LANL, it can be beneficial to observe key topics in Nabi and El-adaway’s article. The industry seems to favor modular construction primarily since it can provide cost savings through economies of scale, among other factors [7]. However, it is essential to note that such positive reviews of modular construction should be tempered with quantitative methods to analyze the

impact of location and other factors on cost-efficiency. Understanding the parameters used to perform a risk-based analysis on modular construction can lead to insights related to reducing the cost of construction at LANL.

B. A Critical Analysis of Benefits and Challenges of Implementing Modular Integrated Construction

The recent interest at LANL with modular construction cost savings warrants the inclusion of an additional article discussing the benefits and drawbacks. The previous article presented a risk quantification strategy associated with modular construction, while Wai *et al.* provide a more holistic examination of the benefits and challenges of modular construction. The article concluded that the benefits outweigh the drawbacks in the long term [8]. However, it also noted that a robust transportation network is required to facilitate the delivery of modular components [8]. This is relevant to LANL because only two roads lead to the campus, and the area is located in a remote region of Northern New Mexico.

The research Wai *et al.* conducted does not consider LANL's circumstance as it relates to radiological hazards, seismic zones, and distinctive customer and security requirements. One item identified in the research does directly apply to LANL, however. The subcontractor and fabricator must be capable and have experience with performing work with LANL. There appear to be many construction firms capable and experienced in modular construction, but very few are capable and experienced at LANL. It is also noteworthy that LANL could realize cost reductions, shortened construction times,

improved construction safety, and enhanced sustainability [8]. In addition, modular construction decreases the subcontractor's dependence on on-site storage, which is seen as a positive at many construction sites across the LANL campus due to a lack of space and environmental concerns. A thorough analysis of LANL's strengths and weaknesses should be conducted before it is determined that modular construction is indeed the path to cost-efficient construction.

C. The Importance and Necessity of Cost Management of Construction Projects

Cost management, also commonly referred to as cost control, ensures construction projects are delivered within time and budget constraints. According to Barbu and Sandu, cost control is an action in which the project's construction cost is handled by the proper approaches and procedures so that the constructor does not experience failure when implementing the project activities [9]. In their article, Barnu and Sandu emphasize the importance of cost management and data-driven estimating techniques for construction projects to assist individuals and groups within the construction industry.

Cost management is vital because once scope, schedule, and cost are defined, cost control is the primary method one can use to keep within the bounds of the three items. Cost management and estimating are heavily dependent on one another: a contributing factor to obstructing effective cost management is inaccurate estimating [9]. Accuracy and precision within estimating are essential to ensuring the cost of construction projects is realistic. For example, an accurate estimate would ensure that the actual cost of building a structure at LANL is correctly captured. In addition, a precise estimate would

be consistent with other estimates. Before we can say the cost of building at LANL is higher than expected, we must understand the actual cost of building at LANL. An accurate and precise estimating methodology underpins the ability to illuminate the contributing factors to the high cost of construction at LANL. At a minimum, this will allow project managers to implement cost control measures consistent with reality. This, in and of itself, may be enough to keep the cost of construction at LANL reasonable.

D. Assessment of Methods for Adjusting Construction Cost Estimates by Geographical Location

Geographical location plays a large part in the cost of construction. A remote location will undoubtedly drive the cost of construction higher, likewise, a convenient location will lower the cost. Standard practice for estimating relies on current Construction Cost Indexes (CCI) produced by various private entities such as RSMeans, Engineering News-Record, and Spons Price Books produced by AECOM, a global engineering services firm. The CCI provides data as it relates to adjusting construction cost estimates for geographical location. This paper, produced by the University of New Mexico, provides increased confidence in CCI related to the location factor. In addition, the paper confirms that using the nearest available approach to characterize the location cost of construction produces the least amount of error [10]. For example, if the nearest available CCI is from Albuquerque, New Mexico, then it is reasonable that this location cost should be used when estimating construction projects at LANL.

This article is significant because the nearest city to LANL is Los Alamos, which is not directly represented in most CCIs. Therefore, when estimating a project, the baseline location cost of construction must be inferred from existing data from a nearby, larger city, historical cost data, standard location multipliers, or other means. This article posits that this method is acceptable and would yield the most accurate results. What this article does not take into account is the location costs of LANL. Aspects unique to the secure location of LANL such as security clearance requirements and checkpoints are not accounted for in this type of location adjustment related to estimating. Part of the solution to build more cost-efficiently at LANL should include location (geographic) cost modifiers and modifiers unique to LANL's situation.

E. Reducing Construction Costs: European Best Practice Supply Chain Implications

The high cost of construction is not limited to Northern New Mexico and Department of Energy facilities. Lessons learned from the European construction market can hold valuable information that can be applied domestically. For example, Proverbs and Holt's journal article focus on construction cost savings realized through supply chain efficiencies. Specifically, they recommend downstream strategic alliances (DSAs) to streamline costs. A DSA refers to a means of aligning mutual, organizational, and project objectives in establishing continuous improvements as it relates to the supply chain in support of the prime contractor [11]. While most strategies to reduce construction costs focus on the work itself, it can be helpful to realize the impact of materials and the supply chain as it feeds into the total cost of a project. For example, if

structural steel's transportation or manufacturing cost for a skyscraper can be reduced by twenty percent, the overall project will save money.

As it relates to construction at LANL, supply chain efficiency techniques such as DSAs are not often considered. This is partly because of federal requirements that limit suppliers and contractors who can operate at LANL. In most circumstances, however, the limitations do not extend to the supply chain downstream of the prime contractor to create and maintain DSAs. Therefore, exploring cost-efficiencies from a supply chain perspective could be one way to reduce the overall cost of construction at LANL.

F. Self-Perform Versus Subcontract Decision in Construction Contracts

In his paper, Nassar presents an Excel-based tool for general contractors to determine the aspects of a job to subcontract versus self-performing the work. The Excel-based solver program represents a linear, quantitative way to minimize costs given available resources and desire to execute a profitable project [12].

In the role of the general contractor, LANL has a qualitative method governed by official LANL administrative procedures to determine if subcontracting or self-performing is the preferred execution strategy. Like the process outlined in Nassar's paper, a quantitative method is not currently in use. LANL could benefit from a more quantitative approach to subcontracting versus self-performing construction work. The downside to a more rigorous assessment of the subcontract vs. self-perform decision is that resources immediately become the central issue for projects within the bounds of this paper. New Mexico has a limited labor pool with a population of only two million,

which is reflected in the number of direct-hire individuals who would enable LANL to self-perform construction activities. Therefore, the constraints are immediately visible: lack of labor. The effects of the COVID-19 pandemic and the Great Resignation have further exacerbated this labor shortage. Were labor to become available, LANL would likely benefit from a more quantitative method of determining if subcontracting or self-performing is better suited for the needs of a specific project.

G. Successful Verification of Subcontracted Work in the Construction Industry

Labor resource shortages, liability, and economic drivers have led LANL to explore subcontracted methods of delivering a construction project in place of self-perform. The author of this paper is familiar with the inspection requirements of a project built on LANL property and to LANL engineering standards. Verification of work performed by prime subcontractors and their lower tiers presents a unique issue at LANL. Often certificate of occupancy, which is granted by the LANL building authority and allows the building to be put into use, is delayed due to a misunderstanding or lack of inspection. In this sense, the terms “inspection” and “verification” are used interchangeably. Makkinga, de Graff, and Voordijk’s research paper identify causes of inspection problems and present improvements intended to ensure projects are not disrupted due to a lack of verification of the work or material. [13]

The research paper resonates with LANL because a cause of cost and schedule overruns can be material incorrectly ordered or received. Inspection and verification of the material (and work) are critical to keeping construction costs low. For example, in

support of a recent renovation project at LANL, new fan coil units were designed and specified by the LANL mechanical engineering team. A fan coil unit is designed to modify airflow to an office space and provide heating and cooling for the individuals working in the office space. When the units arrived on site a few months after they were ordered from a supplier in New Mexico, it was discovered that they were the incorrect models and thus incompatible with the designed electrical supply. Had the material verification been performed before shipping, the correct unit could have been identified, and LANL would have avoided cost and schedule overruns due to the supplier shipping the incorrect unit. This story repeats itself on larger and smaller scales throughout LANL. The ideas presented in the referenced research paper suggest that LANL could benefit from a method whereby materials and designs could be verified father upstream (at conception) rather than waiting until the project execution phase to check compliance.

H. The Importance of Collaboration in Construction Industry from Contractors'

Perspectives

In this article, Rahman et al. evaluate the relationship between the contractor and their subcontractors to determine methods to improve collaboration. The findings showed a strong correlation between increased collaboration and six factors, the most relevant of which are 1) sharing information creates a collaborative environment, 2) familiarity with each parties' contractual responsibilities, and 3) facilitating communication among project members by looking to each party as a business partner [14].

For this paper's purpose, LANL and the contractor are interchangeable terms, meaning LANL is the highest tier contractor who has overall responsibility of the campus, and all other entities who perform work at LANL are referred to as subcontractors.

Collaboration between LANL and its subcontractors is viewed as a desired attribute because collaboration will decrease construction costs from increased efficiency.

Therefore, the factors listed above which contribute to collaboration are items that LANL, as the contractor, should strive to emulate. It is worth noting that the article describes findings related to the Malaysian construction industry, which likely varies significantly from the Northern New Mexico construction industry. However, a point should be made here related to the regional and cultural impact on construction. The success of a construction project in New York would likely be affected by the culture associated with construction in a different way than Northern New Mexico or DOE construction projects. The following article will touch on the influence of culture on construction costs in that regard.

I. An Investigation of the Impact of Cross-Cultural Communication on the Management of Construction Projects in Samoa

This article focuses on cross-cultural communication impacts concerning project management and the construction industry. The article indicates that communication directly affects the success of the project [15]. Success is defined as a positive outcome as it relates to cost, schedule, and scope constraints. Therefore, it is in the best interest of

cost-efficient construction at LANL to understand how culture impacts the success of a construction project.

There appears to be a dearth of information that relates to the construction culture at LANL, or at other DOE National Laboratory facilities across the United States. For example, Tone, *et al.* found that construction in Samoa juxtaposed expatriates that espoused individualistic cultural values with Samoans who exhibited collectivistic cultural values [15]. This further highlights the knowledge gap of Northern New Mexico culture related to the Department of Energy and LANL cultural norms or expectations. The failure to recognize and address mismatched international cultural values can negatively affect a construction project. Just as well, failure to recognize different regional cultural values with respect to construction at LANL can negatively affect a project. This is particularly evident with subcontracted work where the subcontractor is based out of state where cultural values may differ. Awareness of these cultural knowledge gaps most certainly is one of the first steps in implementing a more cost-efficient construction model at LANL.

J. Cost-saving Environmental Activities on Construction Site – Cost Efficiency of Waste Management- Case Study

Processing and disposing of construction waste can have a significant impact on the budget of a construction project. Sobotka and Sagan present three different scenarios or methods of processing construction waste to decrease overall construction costs [16].

This topic of waste disposal is essential because, at LANL, the types of waste generated by some projects can account for up to twenty percent of the total project costs. There are unique requirements that apply to LANL related to safely processing and disposing of these waste streams. Responsibility ultimately rests with the project manager of the construction project, who is also the primary individual responsible for keeping costs within budget. Then, it would make sense that cost efficiencies could be found by ensuring waste is viewed as another way to decrease the total project cost. However, what Sobotka and Sagan's research does not tell us is the best way to cost-effectively treat the unique waste streams generated by some construction projects at LANL. A unique look at LANL's waste generation policies may yield some insight into decreasing the total project cost of construction projects. However, it is also essential to understand the importance of closely following DOE guidelines and regulations related to generating and treating waste streams. Finding a balance between compliance and efficiency may be vital to lowering overall project costs.

K. Early Impacts of the COVID-19 Pandemic on the United States Construction Industry

This paper would be remiss if it did not comment on the impacts of the COVID-19 pandemic on construction costs. Alsharef *et al.* researched the early impacts of the COVID-19 pandemic on the construction industry in the United States. Nearly forty individuals in the construction industry were interviewed. A limiting factor of this article is that New Mexico is not represented in this group. However, the key findings can be

interpreted as applicable to construction at LANL because of the universal impact of the COVID-19 pandemic.

Material delays, delays in inspections and securing permits, reduction in productivity, construction delays, price increases, safety concerns, increase in demand from suppliers, and transition to remote work status were all identified as having a negative cost impact on construction projects [17]. This article only quantifies the initial impacts of COVID-19. On 15 October 2021, LANL saw many employees resign due to a requirement that all employees or subcontractors working on LANL property be fully vaccinated [18]. The impacts of the vaccine mandate will indeed play a role in escalating the cost of construction. Subcontractors, even those with existing contracts, must comply. As a result, subcontractors experience reduced labor pools. With less labor, schedule delays and cost overruns are sure to ensue. This example is one specific case of COVID-19 impacts on LANL related to cost-efficiencies (or, in this case, cost overruns). This paper is likely to identify more COVID-19 related challenges to reducing the cost of construction at LANL. The first step in discovering solutions to a problem, however, is to identify the issues.

V. METHODOLOGY

A. Research Design

This research paper utilizes quantitative and qualitative (mixed mode) research to understand the cause of high construction costs at LANL and suggest solutions to the issue. Quantitative data is processed to test a set of hypotheses; then, more qualitative and quantitative data is gathered to add complementary insight through a questionnaire administered to LANL staff. First, it is hypothesized that the high construction cost is attributed to excessive LANL overhead, often exceeding 15% of TPC. To put that into perspective, a \$17M laboratory facility must include a minimum of \$3M just to build at LANL. One hundred miles South in Albuquerque, NM, the client overhead could be up to 95% less. A second hypothesis for the high cost of construction is that following burdensome codes and standards contrary to regular commercial practices may drive the cost of construction higher at LANL. Finally, the third hypothesis is that the cost of construction merely appears excessive because the baseline data used to estimate a project at LANL is inaccurate or hastily assembled in a “build to budget” fashion, meaning that because of funding limits, projects are estimated at a particular value below that limit in order to obtain funding, when in reality the cost is and should be higher than estimated.

A portion of the research is centered around a survey issued to LANL staff that aims to summarize, categorize and interpret themes surrounding the high cost of building at LANL. Eight reasons for the high construction cost were summarized and presented to

respondents for comment. Respondents were asked to pick the top three reasons for cost inefficiency in construction at LANL. The results are shown below.

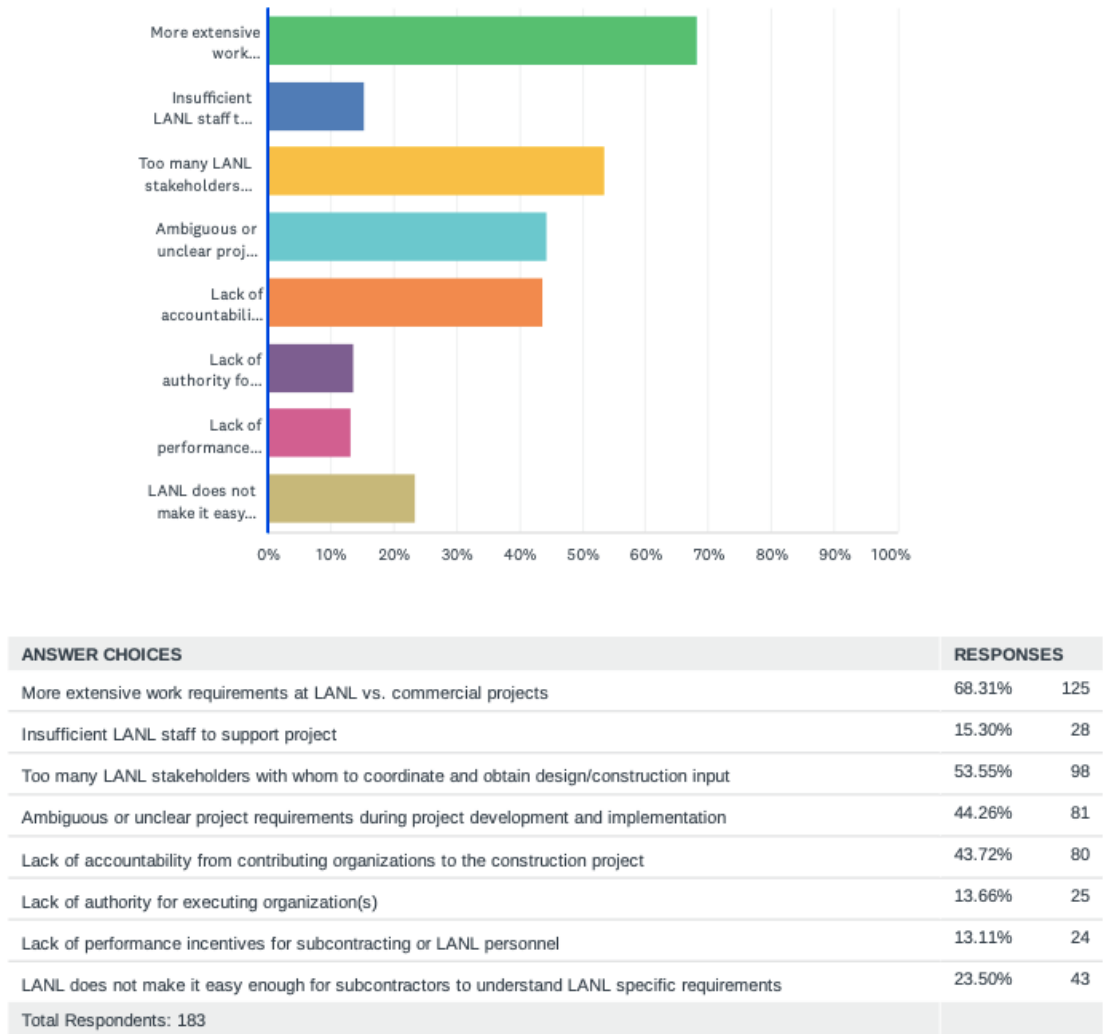


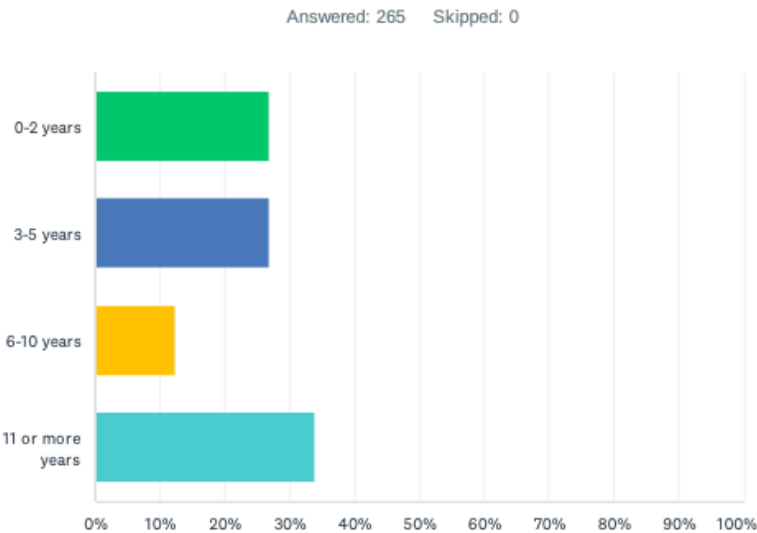
FIGURE V-I REASONS FOR CONSTRUCTION COST INEFFICIENCY

B. Participants

The primary study participants include LANL staff members within the operations group, typically the executing organization for most construction projects at LANL.

Specifically, staff involved in the planning, executing, and managing of capital projects are consulted. In addition, input from another executing organization, the infrastructure program office, is sought. In recent years the infrastructure program office has taken more responsibility for executing work and therefore offers valuable input to this paper. The survey received 265 responses, one-third of which worked at LANL for eleven or more years.

Q1 How long have you been working at LANL?



ANSWER CHOICES	RESPONSES	
0-2 years	26.79%	71
3-5 years	26.79%	71
6-10 years	12.45%	33
11 or more years	33.96%	90
Total Respondents: 265		

FIGURE V-II SURVEY PARTICIPANTS YEARS OF SERVICE

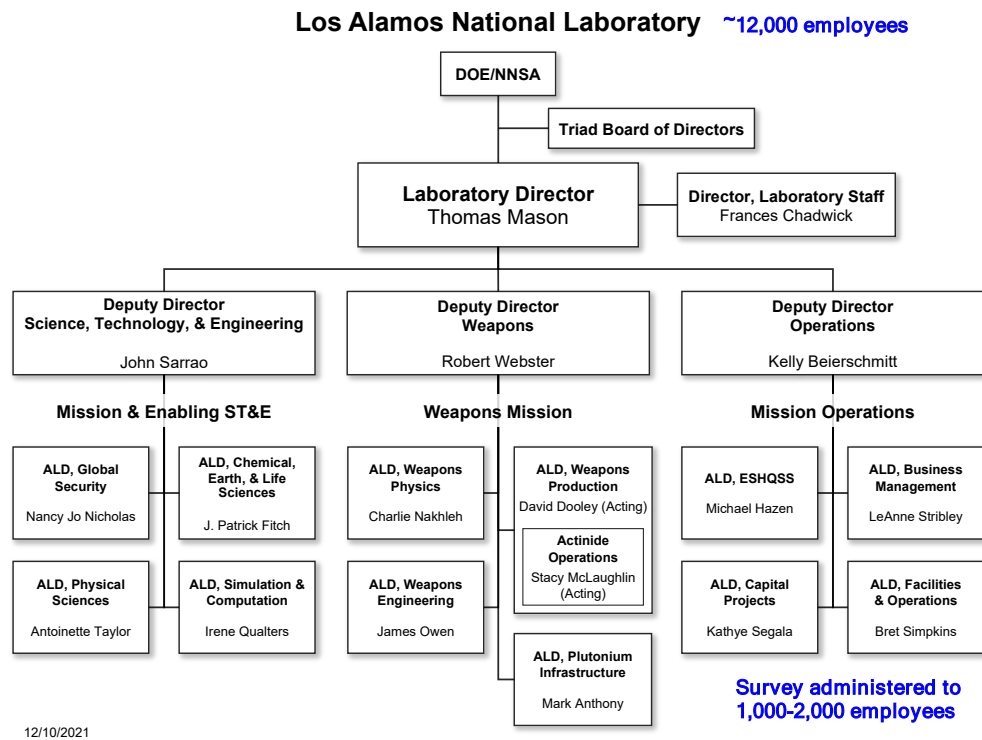


FIGURE V-III SURVEY AUDIENCE

C. Instruments

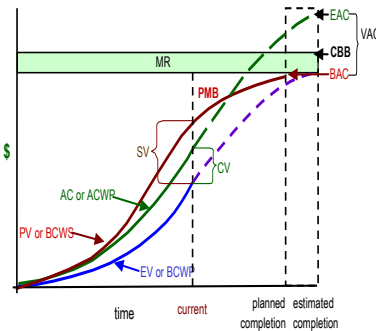
The primary instrument used to analyze a portion of the quantitative data is gathered from previously executed projects utilizing Earned Value Management System (EVMS) criteria per DOE Guide 413.3-10A, which describes EVMS as “an integrated set of policies, procedures, and practices necessary to provide reliable and accurate project and program information to support project management as a decision-making tool and a critical component of risk management.” [19] Cost and schedule variances and performance indices are the primary measures of a successful project. Qualitative data

gathered from the survey compliments EVMS historical data. A more detailed explanation of EVMS is indicated below.

DOE G 413.3-10A
3-13-12

APPENDIX B
B-1 (and B-2)

APPENDIX B—DOE EVMS GOLD CARD



PERFORMANCE BASELINE COMPONENTS

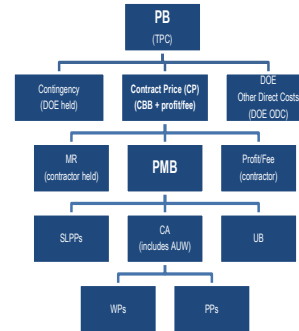
(Performance Baseline must clearly document scope/KPPs, TPC and CD-4 date)

AUW = Authorized Unpriced Work (contractually approved, but not yet negotiated)
CA = Control Account (includes AUW) = WPs + PPs
CBB = Contract Budget Base = PMB + MR
CP = Contract Price = CBB + profit/fee
MR = Management Reserve is held by contractor (Contingency is held by DOE)
PB = Performance Baseline (TPC) = CP + Contingency + DOE ODC
PMB = Performance Measurement Baseline = CAs + UB + SLPPs
PP = Planning Package (far-term activities within a CA)
SLPP = Summary Level Planning Package
UB = Undistributed Budget (activities not yet distributed to CA)
WP = Work Package (near-term, detail-planned activities within a CA)

EVMS BASIC COMPONENTS*

AC = Actual Cost = ACWP = Actual Cost of Work Performed
EV = Earned Value = BCWP = Budgeted Cost of Work Performed
PV = Planned Value = BCWS = Budgeted Cost of Work Scheduled
BAC = Budget at Completion = Σ BCWS = Sum of Budgeted Cost of Work Scheduled

* For analysis purposes, AC, EV and PV calculations may be based on various time periods, e.g., monthly, cumulative, last 3 months from CD-2 or BCP or internal replan.



VARIANCES*

CV = $\frac{EV - AC}{AC}$ = $\frac{BCWP - ACWP}{ACWP}$ = Cost Variance
SV = $\frac{EV - PV}{PV}$ = $\frac{BCWP - BCWS}{BCWS}$ = Schedule Variance
CV% = $\frac{(EV - AC) / EV}{(BCWP - ACWP) / BCWP}$ = Cost Variance (%)
SV% = $\frac{(EV - PV) / PV}{(BCWP - BCWS) / BCWS}$ = Schedule Variance (%)
VAC = BAC - EAC = Variance at Completion

OVERALL STATUS

% scheduled = $\frac{PV_{cum}}{BAC}$ = $\frac{BCWS_{cum}}{BAC}$
% complete = $\frac{EV_{cum}}{BAC}$ = $\frac{BCWP_{cum}}{BAC}$
% budget spent = $\frac{AC_{cum}}{BAC}$ = $\frac{ACWP_{cum}}{BAC}$
Work Remaining (WR) = BAC - EV_{cum} = BAC - BCWP_{cum}

PERFORMANCE INDICES*

CPI = $\frac{EV}{AC}$ = $\frac{BCWP}{ACWP}$ = Cost Performance Index
SPI = $\frac{EV}{PV}$ = $\frac{BCWP}{BCWS}$ = Schedule Performance Index
TCPI_{BAC} = $\frac{WR}{(BAC - ACWP_{cum})}$ = BAC-based To Complete Performance Index
TCPI_{EAC} = $\frac{WR}{(EAC - ACWP_{cum})}$ = EAC-based To Complete Performance Index

COMPLETION ESTIMATES

EAC = BAC / CPI_{cum} = Estimate at Completion (general)
EAC_{CPI} = AC_{cum} + WR / CPI_{cum} = Estimate at Completion (CPI)
EAC_{composite} = AC_{cum} + WR / (CPI_{cum} * SPI_{cum}) = Estimate at Completion (composite)
ETC = EAC - AC_{cum} = Estimated to Complete

FIGURE V-IV EVMS PRINCIPLES [19]

The primary instrument used to administer the qualitative portion of the project is the section of the survey containing three open-ended questions. Questions are formulated

such that the answers are open-ended, and Microsoft Excel is used to provide a thematic analysis.

D. Procedure

The data for the quantitative analysis, specifically the historical cost and schedule data related to past projects, is obtained from the Chief Operating Officer's office of capital projects and the Project Controls group. The financial analyst group has a record of all projects executed since 2018 and provides the data for analysis. The data is provided in categories according to EVMS principles and performance indicators, as shown in Figure V-IV. The data is sorted and placed in categories according to successful and unsuccessful projects aligned with EVMS principles. The baseline data from the estimating group is inherent to the data provided by the financial analyst group since baseline costs determined by the original estimate are representative of the maroon line shown below.

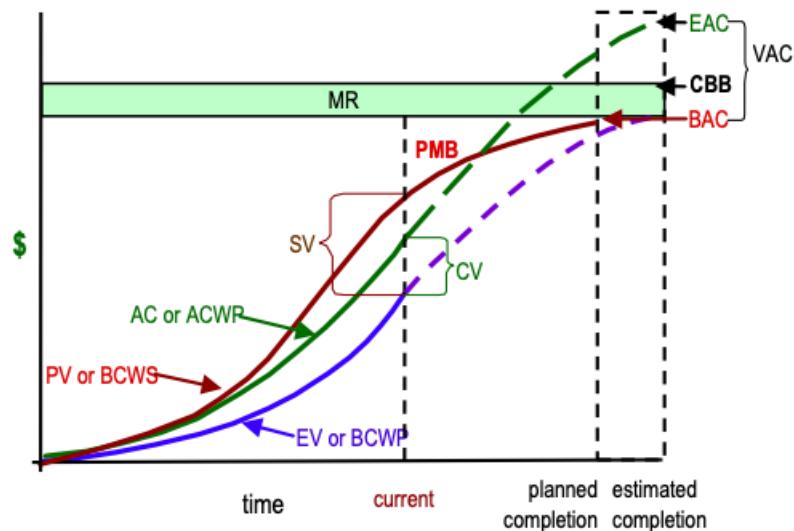


FIGURE V-V BASELINE COSTS: MAROON LINE [19]

The survey is administered through Survey Monkey to undisclosed recipients, as previously indicated in section V.B of this paper. The survey was open for ten business days in January.

E. Data Analysis Plan

1) Quantitative

The historical cost and schedule performance data collected consists of projects executed from November 2018. It is of note that some projects will have finished later than November 2018 because they were initiated by the previous M&O contract with Los Alamos National Security. This data was segregated from the quantitative data set because it does not represent Triad National Security. Therefore, it would skew the interpretation and analysis of the data. The quantitative data is analyzed based on the following criteria:

- Cost Performance
- Schedule Performance

2) Qualitative

The survey consists of open-ended questions analyzed in Microsoft Excel to extract common themes that add insight to the hypothesis proposed in this research paper.

F. Risk Management Process

The risk register below outlines the risks associated with achieving the project objectives. A value of high, medium, or low was assigned to the impact of each item. The impact represents the extent to which the risk could negatively impact the research outcome. For example, a "high" risk impact can potentially halt the project if realized.

Project risks were monitored weekly, and mitigating actions were implemented if any risk indicated below was encountered.

ID	RISK DESCRIPTION	PROBABILITY OF OCCURRENCE	IMPACT	MITIGATING ACTION(S)
1	Baseline data reliability	25%	High	Confirm baseline data is in line with RS Means and industry standards
2	Ability to obtain data	50%	High	Adjust datasets to include available information
3	Usable responses to qual survey	15%	Low	Extract and analyze viable trends
4	Incorrect hypotheses	25%	Low	Validating or invalidating hypotheses will still provide valuable information
5	Separation of projects Triad / LANS	25%	Medium	Ensure clear deliniation between quantitative data sets
6	Cost, schedule and scope not a reliable scale to measure project success	75%	High	Ensure relationships can be determined between projects using cost, schedule and scope as a scale and track accuracy of information

FIGURE V-VI RISK REGISTER

VI. ANALYSIS

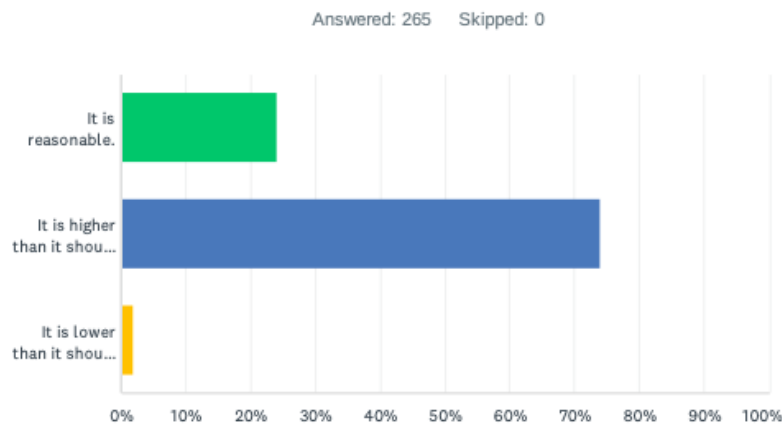
A. Is LANL That Expensive?

To ensure the survey was unbiased, respondents could only provide their input if they believed that the cost of construction at LANL was higher than it should be.

Interestingly, not all respondents believed the cost of construction at LANL was high.

24% of respondents felt that, given the circumstances, the cost of construction was reasonable. While the analysis is performed without the input of those who feel costs are reasonable, it should be noted that a portion of individuals feel that a high cost of construction is valid and reasonable for LANL.

Q3 How do you feel about the cost of construction at LANL?



ANSWER CHOICES	RESPONSES	
It is reasonable.	24.15%	64
It is higher than it should be.	73.96%	196
It is lower than it should be.	1.89%	5
Total Respondents: 265		

FIGURE VI-I COST OF CONSTRUCTION

B. SWOT Analysis

It should not be a surprise that a portion of the quantitative data from the survey reveals strengths and weaknesses related to the high cost of construction at LANL. A strengths, weaknesses, opportunities, and threats (SWOT) analysis of the data obtained in Figure V-I, data from the qualitative portion of the survey, and the project-specific cost performance index (CPI) and schedule performance index (SPI) data suggest that some of the costs inherent to higher overhead are the same items that allow LANL to continue to be one of the leading research facilities in the nation. The deep knowledge base of subject matter experts, not only in the construction and engineering fields, means that LANL often has a high overhead cost and that the input received from the high cost is valuable. Each aspect of a SWOT analysis is explored in depth below.

LANL's strengths include a high concentration of knowledge within the LANL group. These subject matter experts (SMEs) are often in the vanguard of their profession. Pressure safety, electrical code, environment, health, and safety experts most often have advanced degrees and a high degree of specialization, enabling them to contribute that knowledge to projects. Therefore, self-performing construction, in theory, is advantageous where possible. The SME knowledge and high standards also result in a quality product.

Weaknesses are represented in the view of both LANL personnel and the subcontractor. One of the primary weaknesses is the remote location of LANL. The

location has knock-on effects which drive up the cost of construction due to transportation costs and decrease the amount of available labor for LANL and the subcontractor. In addition, the stringent security requirements for workers, high cost of living in a remote area, and the COVID-19 vaccine requirement that started in the fall of 2021 also represent weaknesses that translate into a higher cost of construction.

One threat that LANL faces is the loss of funding if projects continue to be more expensive than other laboratories and commercially comparable projects. Without the proper facilities to support LANL's mission, there is the possibility that LANL will fail to meet its mission objectives for the DOE. Finally, the inability to decrease the cost of construction could irreparably damage the reputation of LANL since it would no longer be capable of solving national security challenges through simultaneous excellence [2] [20].

Finally, and most importantly, there are many opportunities for LANL to lower the cost of construction. Increased communication between LANL entities and subcontractors may be one area of improvement. Offering performance-based incentives for LANL employees and subcontractors may increase efficiency and decrease construction costs. Sharing the risk of building with subcontractors through commercialized construction integrated project delivery methods is another area of improvement for LANL. For example, Construction Manager at Risk (CMAR or CMR) is not currently utilized at LANL, which suggests an adherence to Design-Bid-Build (DBB) or Design-Build (DB) methods of construction. These methods will likely yield

results similar to historical cost and schedule overruns. An opportunity for LANL is to leverage CMAR and an integrated project delivery method “by carefully synchronizing both the design contract and the CMR preconstruction services contract” [20].

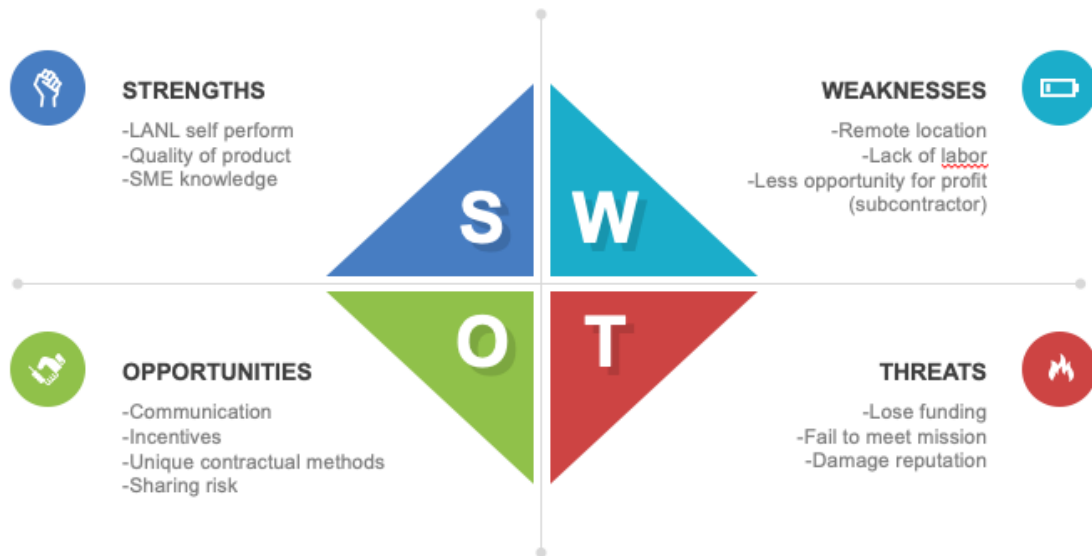


FIGURE VI-II SWOT ANALYSIS

C. PESTLE Analysis

A political, economic, social, technological, legal and environmental (PESTLE) analysis is intended to provide strategic insight on a macro level for LANL to become more competitive in their ability to execute projects cost-effectively. The addition of legal and environmental factors to the standard PEST model was pertinent due to the stringent requirements related to DOE work and these factors.

The political factors that influence the cost-effectiveness of construction are of significant impact. LANL’s project execution organization operates through a matrixed organizational structure. 54% of survey respondents believed that too many stakeholders

were a cause of the high construction cost. A common theme throughout the qualitative portion of the survey was that to accomplish a goal, executing organizations and individuals had to navigate through a political maze to secure support and accomplish tasks related to the project. A project leader with clear, ultimate support and the same agenda as other matrixed organizations is vital to efficiently executing a project.

Economic factors (funding availability) can influence the ability to execute projects but were found to have a negligible effect on the project's cost-effectiveness. Still, the differences between commercial practices and government contracting should not be discounted. In a typical commercial application, the entirety of the project funds is available to the investor or client prior to engaging the executing organization. At LANL, the executing organization often has to wait until funding is released to perform various tasks related to the project execution. However, the ability to streamline and commercialize the funding issues at LANL is non-negotiable due to LANL's contract with the DOE. Utilizing alternate funding sources to support project-related goals within the bounds of the DOE Financial Management Handbook [21] can offer a path to execute a project in a cost-efficient manner by allowing costs outside the project to be absorbed by alternate funding streams often not affected by fiscal year availability.

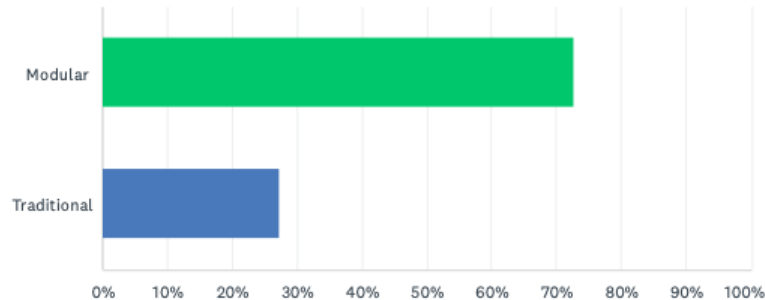
The social impacts, or work culture at LANL, were not explored in depth through the survey or historical cost and schedule data. The reader must be aware of the impact of the work culture on a project's ability to be executed in a cost-efficient manner. As LANL explores new ways of executing projects differently and invites new

subcontractors to execute work at LANL, understanding the potential cultural impacts of organizationally effective subcontractors on the cost-effectiveness of a project [22] should not be discounted.

The qualitative portion of the survey indicated that technological advancements in construction were not fully utilized at LANL. Historical CPI/SPI indicators of modular buildings do not appear to yield more cost-efficiency than traditional construction (cast in place concrete) methods. Interestingly, survey data suggests that 73% of respondents believe modular construction is cheaper than traditional construction. However, the utilization of tilt walls, precast panels, and unique foundation designs such as geo piers [23] could add to the cost-effectiveness of construction at LANL. Attracting new talent to LANL with a track record of successfully executing construction projects maximizing or tailoring technological advancements in construction techniques and designs will be crucial to reducing the cost of construction at LANL.

Q4 Modular construction is defined as fabrication, integration, and assembly of components of a constructed structure or facility at manufacturing plants that then are transported to the construction site (Bayraktar, Hastak, & Gokhale, 2011). Traditional construction refers to a building method where the project is constructed primarily on site. Which construction method do you perceive as most effective in reducing costs?

Answered: 183 Skipped: 82



ANSWER CHOICES	RESPONSES	
Modular	72.68%	133
Traditional	27.32%	50
Total Respondents: 183		

FIGURE VI-III MODULAR VS. TRADITIONAL CONSTRUCTION AT LANL

Finally, work at LANL presents unique legal and environmental challenges. These can be addressed by increasing communication efforts with potential and established subcontractors to ensure awareness of these requirements. Because LANL is responsible to a federal organization, there is little room for negotiation related to these subjects. However, there is room for streamlining processes and procedures to implement legal and environmental requirements at LANL. Communication and collaboration within LANL teams and subcontractors and utilizing an integrated project delivery planning

and execution method emerged as a central theme throughout the survey as an opportunity to improve upon these organizational factors on a macro level.

P Political	E Economic	S Social	T Technological	L Legal	E Environmental
Competing agendas, uncoordinated across the LANL campus	When / how funding is available	Work culture	Use of technology to aid in cost reduction (tilt wall, precast panels, unique foundation designs)	Acquisition Service Management (ASM) – utilize commercialized contract structures	Impact of environmental requirements to projects – bottom line up front (BLUF) to subcontractors

FIGURE VI-IV PESTLE ANALYSIS

D. Pareto Chart / Root Cause Analysis (RCA)

When the survey responses regarding the high cost of construction are analyzed through a Pareto Chart, it becomes apparent that respondents feel that 80% of the high costs are due to more extensive work requirements at LANL when compared to the commercial world, too many stakeholders involved in the project, unclear project requirements as it relates to project scope and lack of accountability.

Based on the open-ended survey responses, it is surmised that the root cause of the high cost of construction may be related to the cultural norms and experience of the integrated project delivery team at LANL. 34% of respondents have been at LANL for eleven or more years, so the responses can be linked to a depth and breadth of organizational knowledge regarding how business has been conducted and projects have

been executed in the past. Outside of the quantitative data obtained in the survey, an interpretation of the qualitative results suggests that the remote location of LANL, lack of teamwork and communication across LANL organizations, and lack of subcontractors/vendors willing to work at LANL contribute to the high cost of construction. In order to attract subcontractors to do business with LANL, the cost of a building can be higher than at other locations throughout the United States that may be cheaper for the subcontractor to build the same building.

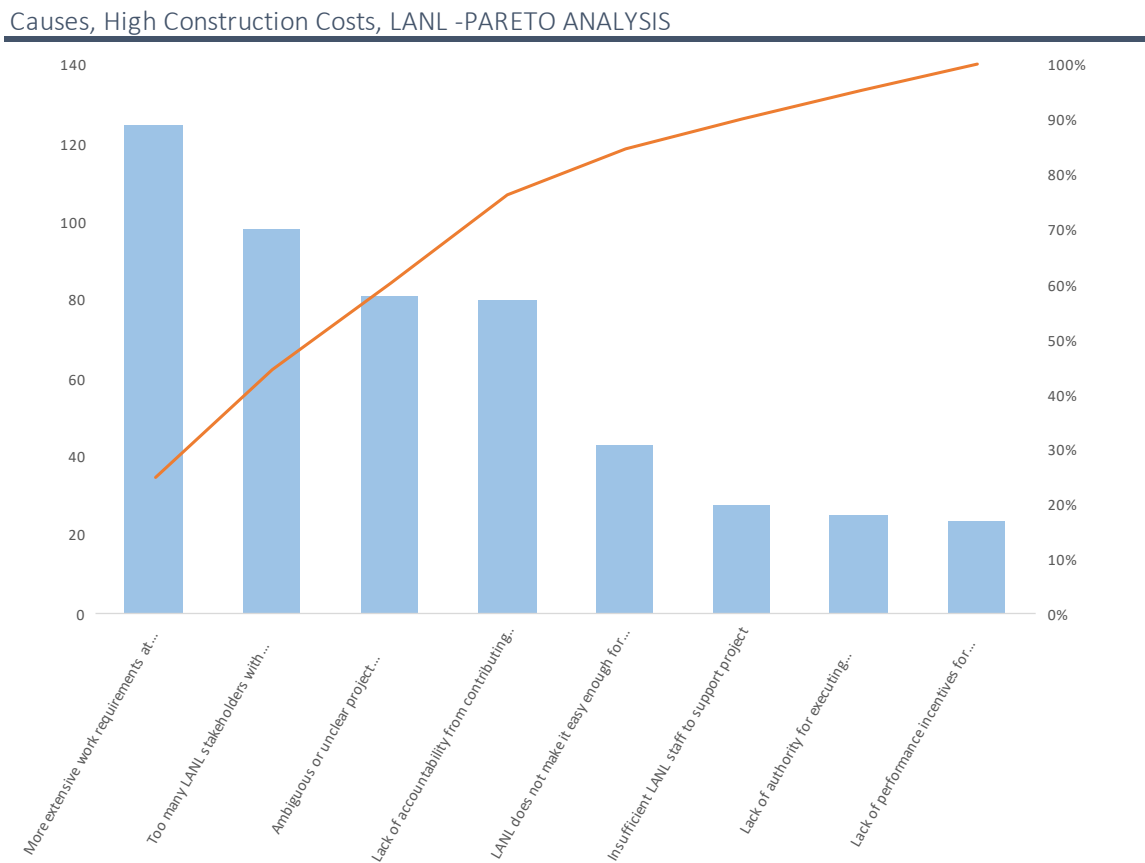


FIGURE VI-V HIGH CONSTRUCTION COSTS – PARETO ANALYSIS

PROBLEM DATA

PROBLEM AREA	OCCURRENCES	PERCENT OF TOTAL	CUMULATIVE PERCENT
More extensive work requirements at LANL vs. commercial projects	125	24.80%	24.80%
Too many LANL stakeholders with whom to coordinate and obtain design/construction input	98	19.44%	44.25%
Ambiguous or unclear project requirements during project development and implementation	81	16.07%	60.32%
Lack of accountability from contributing organizations to the construction project	80	15.87%	76.19%
LANL does not make it easy enough for subcontractors to understand LANL specific requirements	43	8.53%	84.72%
Insufficient LANL staff to support project	28	5.56%	90.28%
Lack of authority for executing organization(s)	25	4.96%	95.24%
Lack of performance incentives for subcontracting or LANL personnel	24	4.76%	100.00%

FIGURE VI-VI DATASET FOR PARETO ANALYSIS

E. CPI / SPI Analysis

An analysis of CPI and SPI data related to a specific subset of projects within WIPO during the January 2022 period indicates that most projects are performing better than forecast regarding cost but worse than forecast regarding schedule. It is important to note that the projects in the data set are all in progress. When cumulative CPI and SPI are viewed, it becomes apparent that fewer projects have both a CPI and SPI above one, meaning that the project receives an amount significantly less for every planned day and dollar of work. For example, each dollar spent translates to .85 cents for the RLUOB Secondary Fire Pump project.

CPI and SPI are indicators that are typically reserved as project management tools.

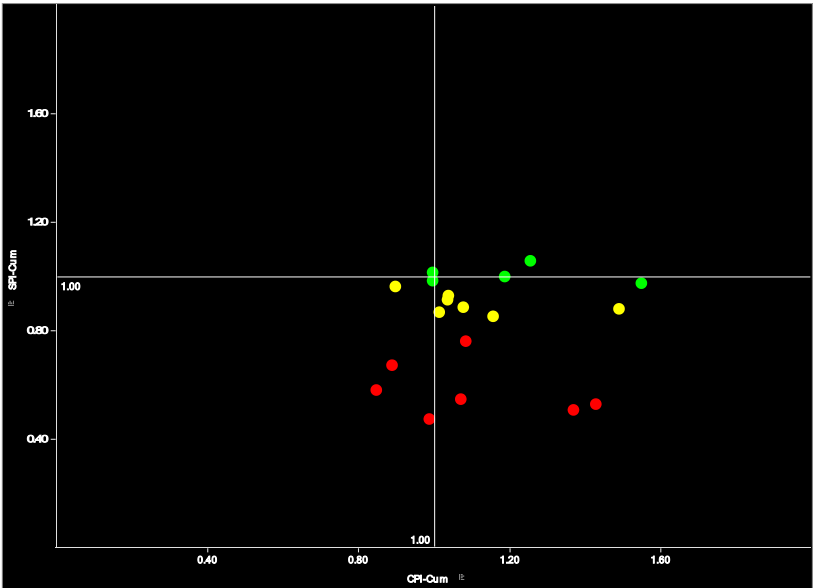
The reader may wonder how an analysis of these indicators would contribute to identifying the cause of the high cost of construction. CPI and SPI indicators are included here because they present information that challenges the notion that all projects experience cost overrun. In our data set, for January 2022, 80% of the projects performed better than expected related to their overall project cost. However, the data presented here does not consider completed projects, which tells us that many projects may seem cost-effective until they are completed, and all outstanding issues are resolved. Therefore, many of the issues contributing to the high construction cost may present themselves in the latter stages of a project.

ALDCP_ProjectReport V39

ALDCP Portfolio - Performance - Portfolio Table

Project Name	PID	% Complete	BAC	EAC	SPI-Cum	CPI-Cum	TCPI (EAC)	CPI-TCPI Variance
Forming & Fabrication Equipment Upgrades (New Press)	104058	1%	\$5,550K	\$5,550K	0.62	2.16	1.00	1.16
PF-4 High Pressure Water Supply Feed Separation	103776	11%	\$6,430K	\$6,399K	0.53	1.43	0.97	0.46
TA15 DARHT Electrical Circuit Upgrade	103785	15%	\$10,387K	\$10,355K	0.97	1.55	0.94	0.60
LANSCE LLRF Cavity Field Control Improvements	103898	25%	\$10,489K	\$10,638K	0.89	1.08	0.96	0.12
TA03-0066 SIGMA - Flow Form Installation	105032	27%	\$5,199K	\$5,199K	1.01	1.00	1.00	(0.00)
TA-41-0004 D&D	103876	27%	\$10,354K	\$10,296K	0.88	1.49	0.90	0.60
Sigma Uranium Foundry	103685	31%	\$10,272K	\$9,988K	1.06	1.26	0.95	0.31
TA-16-0260 Pressing Machining Testing Facility Upgrade	103777	46%	\$12,457K	\$15,700K	1.00	1.19	0.62	0.57
KCH4 CMR Wing 2 & 5	103949	47%	\$3,663K	\$3,539K	0.47	0.99	1.08	(0.10)
TA-3-39 HVAC Split System	105125	50%	\$5,709K	\$5,949K	0.96	0.90	1.03	(0.13)
KCH5 - Wing 3 Main Floor Nuclear Fixed Contamination Reduction	104050	51%	\$1,454K	\$1,561K	0.51	1.37	0.70	0.67
TA08 HE Shipping Transfer Facility	103852	55%	\$7,930K	\$7,960K	0.55	1.07	0.92	0.15
RLUOB Secondary Fire Pump	103851	56%	\$4,182K	\$4,581K	0.58	0.85	1.01	(0.16)
TA-16-411 Assembly Facility Mudroom	103706	65%	\$4,189K	\$4,831K	0.67	0.89	0.83	0.06
D&D TA22 and TA37 Magazines	103878	69%	\$3,107K	\$3,169K	0.76	1.08	0.81	0.28
TA-03 Substation Replacement_Reassigne Scope	102390	85%	\$3,858K	\$4,450K	0.85	1.16	0.35	0.80
Clarifier 1 Stabilization	103770	87%	\$5,007K	\$6,463K	0.87	1.01	0.30	0.71
CMR Wing 3 Main Floor Nuclear Fixed Contamination Reduction Through Component Removal	103929	91%	\$2,550K	\$3,279K	0.91	1.04	0.22	0.82
TA-16-0306 Demolition	103874	93%	\$5,939K	\$5,933K	0.93	1.04	0.69	0.35
TA-16-0460 Complex Disposition (D&D)	103875	98%	\$5,308K	\$5,892K	0.98	1.00	0.14	0.86

FIGURE VI-VII CPI/SPI PROJECT DATASET, JAN 2022



1/1

FIGURE VI-VIII CUMULATIVE CPI/SPI, JAN 2022

VII. RETURN ON INVESTMENT

The ROI is best visualized through an archetypal LANL construction project. The project represents a typical subcontracted, DB, twenty thousand square-foot office building valued at \$18.6M before LANL overhead. At a fixed burdened rate, if at least one of the recommendations of this paper is implemented and LANL overhead costs of labor, expense, Title II, and Title III support are reduced by 50%, the TPC of the project shrinks, resulting in an ROI of 11%. The ROI here is calculated as (Net Return on Investment/Cost of Investment) x 100%, or (\$2,939,529 / \$26,357,719) x 100%.

Ostensibly, the 11% ROI or overall reduction in TPC is the sum of reducing extensive LANL work requirements versus commercial projects and reducing the amount of obfuscation surrounding a construction project due to excessive or unclear stakeholder input and involvement.

								Sample Project Cost Before	Sample Project Cost After	Potential Savings (ROI)
	Building Square Footage							20,000	20,000	20,000
	DIRECT COSTS									
	Total Factored Construction Cost + Equipment Cost							\$ 18,693,032	\$ 18,693,032	\$ 18,693,032
		Corporate Loads								
		LANL Burden (Recharge)		15.3%				\$ 2,519,147	\$ 2,519,147	\$ 2,519,147
		LANL Labor		12.0%	6.0%			\$ 1,975,802	\$ 987,901	\$ 1,975,802
		LANL Expense		6.0%	3.0%			\$ 987,901	\$ 493,950	\$ 987,901
		Title II		8.0%	4.0%			\$ 1,317,201	\$ 658,601	\$ 658,601
		Title III		3.0%	1.5%			\$ 493,950	\$ 246,975	\$ 246,975
		LANL Management Reserve		10%	Applied to total cost			\$ 2,598,703	\$ 2,046,601	\$ 552,102
		Total Corporate Loads						\$ 9,892,705	\$ 6,953,175	\$ 2,939,529
		Total						\$ 26,357,719	\$ 23,418,189	\$ 2,939,529

FIGURE VII-I ROI

VIII. RECOMMENDATIONS AND CONCLUSION

A. Recommendation 1: Reduce LANL Overhead

By reducing LANL overhead, the TPC of construction projects can decrease by 11% or more depending on the level of efficiency achieved. Reducing LANL overhead can happen in several ways. First, LANL should invest time, effort, and expertise in a project's planning and definition phases. Suppose the necessary time and resources are allocated to these project phases. In that case, it will result in more minor issues during the project execution and closeout phases and less LANL overhead required to resolve those issues. Second, LANL should clearly communicate project-related requirements to the subcontractor through the subcontract documents and interpersonal relationships between the LANL project team and the subcontractor project team. Clear lines of communication, both contractually and verbally, help reduce LANL overhead. Lastly, LANL should strive to streamline and manage LANL stakeholder involvement. The author notes that some stakeholders do not directly charge the project for their services, resulting in a lower TPC. In contrast, some LANL stakeholders must utilize the project cost code for their services, resulting in a higher TPC. While the scope of this paper did not explore this phenomenon, it is worth noting that a solution to reduce the cost of construction could be to explore funding streams that allow for a high level of stakeholder involvement, but a low project cost associated with the stakeholders. Note that these practices should be within the bounds of DOE policy.

B. Recommendation 2: Streamline Construction Codes / Standards

It is recommended that LANL streamline or tailor construction codes and standards using a graded approach to building type and function to reduce construction costs. The master contract between the M&O firm (Triad National Security, LLC) and the DOE/NNSA indicates construction standards and code requirements. An in-depth analysis of the current master contract and current LANL policies and procedures may reveal efficiencies in the construction realm. That is to say, in the commercial world, each construction project is unique and evaluated as such. Many construction codes and standards are universal throughout federal, state, county, and city jurisdictions. However, applying these codes and standards can vary greatly depending on the building function, soil type, climate, architectural desire, use, and so on. In the spirit of applying a more commercial mindset to the execution of work at LANL, it is recommended that a process to evaluate each building or project in accordance with its mission, requirements, and client preference is implemented to reduce the overall cost of building. In essence, a streamlined, tailored approach should be adapted to each building or project to maximize cost-effectiveness.

C. Recommendation 3: Explore New Construction Techniques

A new topic of debate at LANL is whether or not to use modular construction techniques to achieve cost-efficient construction. The findings of this paper confirm that most LANL personnel view modular construction as more cost-effective than traditional building techniques. Two concepts emerge from this view that could reduce construction

costs. First, novel construction techniques may help drive the cost of construction lower. Modular, precast, and tilt-wall construction methods, geo pier foundation solutions, bolted steel frames with corrugated steel concrete decks and glazed exteriors, and SpeedCore [24] construction techniques are a few concepts that LANL should keep an open mind to considering. Ultimately, LANL should allow the subcontractor the opportunity to be profitable through encouraging and supporting the use of novel construction techniques. Second, novel subcontracting vehicles should be explored for each building. For example, CMAR, DB, DBB should all be tailored along with the needs of each building or project.

D. Conclusion

There are many opportunities for LANL to become more efficient at building new infrastructure to support its growing mission needs and replace its aging infrastructure. This paper explores a few key concepts to determine the cause of high construction costs and then attempts to provide solutions to reduce the cost of construction. Of all the topics explored in this research paper, the most important item to note is that to be successful, the entire organization must embrace teamwork in pursuit of the same goals. Teamwork, in this situation, requires an open mind and a willingness to do things differently. It is the hope of the author of this paper that LANL is willing to embrace these ideas and implement them in pursuit of supporting national security and scientific excellence.

IX. REFERENCES

- [1] K. Coggeshall, V. Grant and W. Spivey, "Pit Production Explained," 13 December 2021. [Online]. Available: <https://discover.lanl.gov/publications/national-security-science/2021-winter/pit-production-explained>. [Accessed 8 March 2022].
- [2] Los Alamos National Laboratory, "<https://www.lanl.gov/>," [Online]. Available: <https://www.lanl.gov/mission/index.php>. [Accessed 16 October 2021].
- [3] T. R. Fehner and F. G. Gosling, "The Manhattan Project," US Department of Energy Office of Management, Executive Secretariat, and History and Heritage Resources, 2012.
- [4] Triad National Security, LLC, "<https://triadns.org/>," 2018. [Online]. Available: <https://triadns.org/triad-national-security-llc-begins-management-transition-at-los-alamos-national-laboratory/>.
- [5] M. Frank, "U.S. Department of Energy Directive Program, Office of Management," 12 January 2021. [Online]. Available: <https://www.directives.doe.gov/directives-documents/400-series/0413.3-BOrder-b-chg6-ltdchg>. [Accessed 22 October 2021].
- [6] M. E. Bayraktar, M. Hastak and S. Gokhale, "Decision Tool for Selecting the Optimal Techniques for Cost and Schedule Reduction in Capital Projects," *Journal of Construction Engineering Management*, vol. 137, no. 9, pp. 645-655, 2011.

- [7] M. A. Nabi and I. H. El-adaway, "Risk-Based Approach to Predict the Cost Performance of Modularization in Construction Projects," *Journal of Construction Engineering and Management*, vol. 147, no. 10, 2021.
- [8] C. T. Wai, P. W. Yi, O. I. Olanrewaju, S. Abdelmageed, M. Hussein, S. Tariq and T. Zayed, "A Critical Analysis of Benefits and Challenges of Implementing Modular Integrated Construction," *International Journal of Construction Management*, vol. 21, 2021.
- [9] A.-M. Barbu and M. Sandu, "The Importance and Necessity of Cost Management of Construction Projects," *Urbanism. Arhitectura. Constructii.*, vol. 11, no. 2, pp. 215-224, 2020.
- [10] G. C. Migliaccio, P. Zandbergen and A. A. Martinez, "Assessment of Methods for Adjusting Construction Cost Estimates by Geographical Location," *AACE International Transactions*, 2009.
- [11] D. G. Proverbs and G. D. Holt, "Reducing Construction Costs: European Best Practice Supply Chain Implications," *European Journal of Purchasing & Supply Management*, vol. 6, no. 3-4, pp. 149-158, 2000.
- [12] K. Nasser, "Self-Perform Versus Subcontract Decision in Construction Contracts," *AACE International Transactions*, 2003.

- [13] R. Makkinga, R. de Graaf and H. Voordijk, "Successful Verification of Subcontracted Work in the Construction Industry," *System Engineering*, pp. 21:131-140, 2018.
- [14] S. H. A. Rahman, I. R. Endut, N. Faisol and S. Paydar, "The Importance of Collaboration in Construction Industry from Contractors' Perspectives," *Procedia Social and Behavioral Sciences*, vol. 129, pp. 414-421, 2014.
- [15] K. Tone, M. Skitmore and J. K. W. Wong, "An Investigation of the Impact of Cross-Cultural Communication on the Management of Construction Projects in Samoa," *Construction Management & Economics*, vol. 27, no. 4, pp. 343-361, 2009.
- [16] A. Sobotka and J. Sagan, "Cost-saving Environmental Activities on Construction Site - Cost Efficiency of Waste Management - Case Study," *Procedia Engineering*, vol. 161, pp. 388-393, 2016.
- [17] A. Alsharef, S. Banerjee, S. M. J. Uddin, A. Albert and E. Jaselskis, "Early Impacts of the COVID-19 Pandemic on the United States Construction Industry," *International Journal of Environmental Research and Public Health*, vol. 18, no. 4, 2021.
- [18] Los Alamos National Laboratory, "www.lanl.gov," 15 October 2021. [Online]. Available: https://www.lanl.gov/newsroom/_assets/pdf/1015-POL1201-6_R22.pdf. [Accessed 21 October 2021].

- [19] F. Melvin, "DOE G 413.3-10A Chg 1 (Admin Chg), Earned Value Management System (EVMS)," 22 October 2015. [Online]. Available: <https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-10a-admchg1>. [Accessed 12 November 2021].
- [20] J. S. Shane and D. D. Gransberg, "A Critical Analysis of Innovations in Construction Manager-at-Risk Project Delivery," in *Construction Research Congress 2010: Innovation for Reshaping Construction Practice*, Banff, Alberta, Canada, 2010.
- [21] U.S. Department of Energy, "<https://www.energy.gov/>," 08 June 2016. [Online]. Available: https://www.energy.gov/sites/default/files/2021-10/doe-financial-management-handbook-complete_0.pdf. [Accessed 09 February 2022].
- [22] V. Coffey, *Understanding Organisational Culture in the Construction Industry*, New York: Spon Press, 2010.
- [23] Geopier, "<https://www.geopier.com/>," Geopier Foundation Company, 2021. [Online]. Available: <https://www.geopier.com/>. [Accessed 9 February 2022].
- [24] J. Traut-Todaro, "www.structuremag.org," November 2019. [Online]. Available: <https://www.structuremag.org/wp-content/uploads/2019/10/261911-C-BuildingBlocks-Todaro.pdf>. [Accessed 10 May 2022].

APPENDIX A

LIST OF ACRONYMS

ALDCP	Associate Laboratory Directorate, Capital Projects
CCI	Construction Cost Index
CMAR, CMR	Construction Manager at Risk
CPI	Cost Performance Index
DB	Design Build
DBB	Design-Bid-Build
DOE	Department of Energy
DSA	Downstream Strategic Alliance
EVMS	Earned Value Management System
LANL	Los Alamos National Laboratory
M&O	Management and Operating
NNSA	National Nuclear Security Administration
	Political, Economic, Social, Technological, Legal,
PESTLE	Environmental
RCA	Root Cause Analysis
ROI	Return on Investment
SME	Subject Matter Expert
SPI	Schedule Performance Index
SWOT	Strengths, Weaknesses, Opportunities, and Threats

TPC	Total Project Cost
WIPO	Weapons Infrastructure Program Office